THE INFLUENCE OF AGRICULTURAL PRACTICE ON SOIL MICRO-ARTHROPOD POPULATIONS

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Cultivation decreased the number of species of arthropods in soil and the numbers of Collembola, Pauropoda and oribatid mites (Cryptostigmata, Acarina). It only slightly affected numbers of other Acarina, Symphyla, Diplopoda and Protura. Species with a short life cycle repopulated cultivated soil within a single growing season. Some insects were much fewer in cultivated land than in pasture or woodland. When old grass was ploughed numbers of wireworms diminished but recovered in three years when the land was reseeded with grass; by contrast, when planted to lucerne they continued to diminish.

Organic manure greatly increased numbers of Collembola and Acarina and inorganic fertilizers caused small increases. Raising the pH of the soil increased numbers of some micro-arthropods but decreased those of others.

Pesticides greatly changed the numbers and decreased the diversity of species of micro-arthropods in soil. Some species increased greatly, especially after treatment with organophosphate insecticides, because their principal predators were killed.

INTRODUCTION

The processes used to grow agricultural crops, such as cultivation of the soil, the use of fertilizers and pesticides, rotations of crops, irrigation and drainage, all affect the soil microflora and microfauna, altering them quantitatively and qualitatively. The change from a wide range of plant species to a single crop may favour individual species of arthropods so that they become pests, but many other species may be drastically decreased in numbers or eliminated. Individual species of arthropods often become pests because their principal predators or parasites are lacking.

Cultural operations interact with each other in their effect on soil arthropods: some act in the same direction and others in opposition so changing the relative numbers of different species. This paper describes the influence of some agricultural operations on soil arthropod populations in studies made at Rothamsted during the past fifteen years. Complete details of all the experiments cannot be given here, but the conclusions are based on data obtained from adequately replicated field experiments. Soil cores ranging from 2 to 4 in. (*ca.* 50–100 mm) in diameter and 6 to 8 in. (*ca.* 150–200 mm) deep were taken periodically from the experimental plots. The arthropods were extracted from the samples either by a modified Salt and Hollick flotation method (RAW, 1955) or with Tullgren funnels (EDWARDS, 1970).

EFFECTS OF CULTIVATION ON POPULATIONS OF SOIL MICRO-ARTHROPODS

The vertical distribution of soil micro-arthropods differs in woodland, pasture and arable soils. In woodland soils, most animals are in the litter layer and numbers

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decrease in the deeper layers of soil. In pasture most are within 2 in. of the surface, in the mat or organic matter at the base of the plants and among roots, but, by contrast, in arable land the animals are much more evenly distributed through the upper 6 in. of soil. The different groups of micro-arthropods differ considerably in their vertical distribution in the soil and this affects their susceptibility to cultural operations.

Many insect larvae, some millipedes and centipedes, isotomid, entomobyrid and sminthurid Collembola, and many species of Acarina, live at or near the soil surface. Insects such as chafers, wireworms, carabid and swift-moth larvae, as well as Protura, some millipedes, onychiurid and podurid Collembola and some Acarina, especially Rhodacaridae and Tyroglyphidae, are common to a depth of 6 in. in the soil. Symphylids, Diplura and pauropods often penetrate the soil to a depth of several feet and some Acarina and Collembola occasionally occur even deeper. In a field that had been pasture for about 300 years, samples were taken immediately before it was ploughed and disked and again two weeks later. *Figure 1*, which summarizes the changes in numbers of the different groups of arthropods, shows that whereas Prostigmata, Mesostigmata, Symphyla, Diplopoda, Protura and Insecta were not greatly affected by the cultivation, the Cryptostigmata, Collembola and Pauropoda became much fewer.

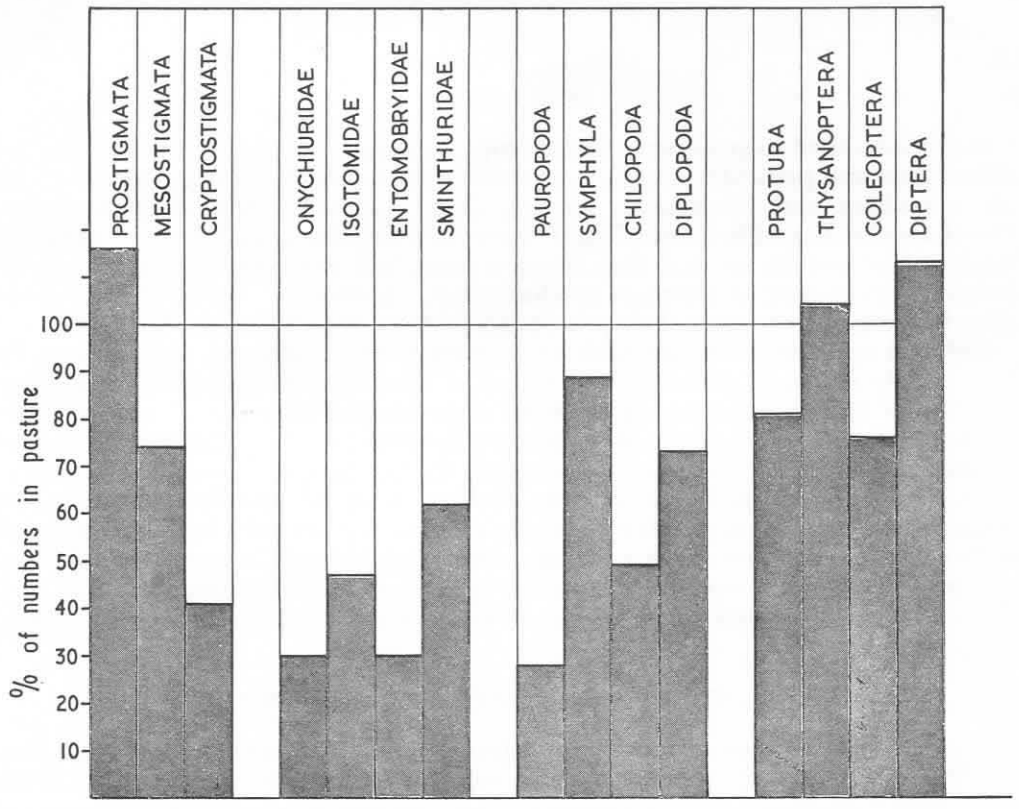

FIGURE 1. Effect of ploughing out of pasture on numbers of soil arthropods.

Similar changes occurred in an experiment in which the numbers of arthropods in unploughed soil, treated with the herbicide paraquat and immediately seeded with wheat, were compared with those in plots ploughed and then sown with wheat. Samples were taken two and six months after the crops were planted. *Figure 2* shows that Prostigmata, Mesostigmata and surface-living Collembola were not much affected by the treatments, but the numbers of Cryptostigmata and deep-living Collembola were at first greatly decreased. However, after six months, the numbers of these groups of arthropods on ploughed and unploughed plots differed much less, indicating that effects would not persist into a second season.

Comparisons of the numbers of arthropods in woodland, pasture and arable habitats on each of three soil types, peat, clay-loam and sandy-loam, showed that the oribatid mites were most numerous in woodland, less so in pasture and fewest in

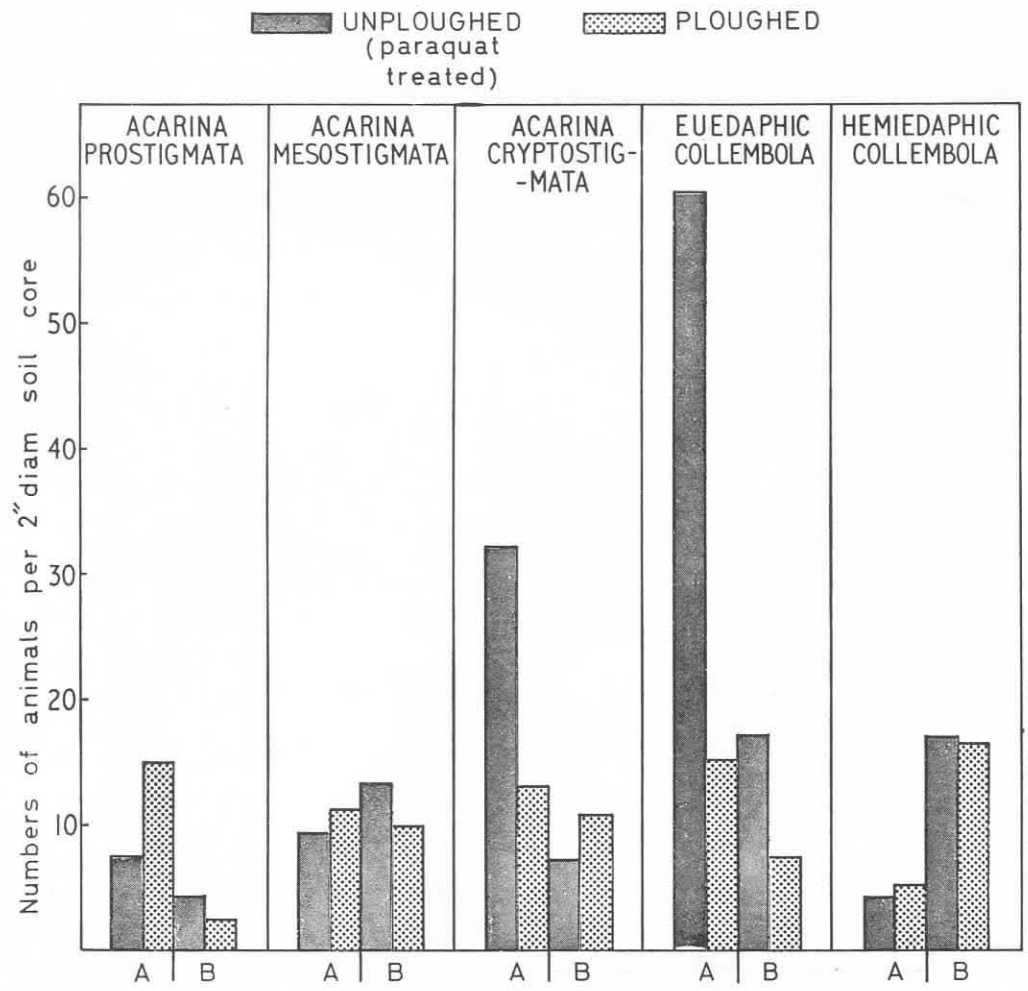

FIGURE 2. Comparison of soil micro-arthropod populations in ploughed and herbicide (paraquat)-treated plots. Population levels two months (A) and six months (B) after treatment and planting with wheat.

arable soil. Other arthropods were less affected but clearly arable land supports fewer arthropods than either woodland or pasture, and woodland usually contains most animals. The soil type also influences the numbers of arthropods in the three habitats.

When grassland is ploughed and sown, the subsequent crops are often seriously damaged by wireworms, chafers, swift moth larvae and leatherjackets. This is because grassland supports more of these arthropods than most other crops. With continued cultivation the numbers of these pests, all of which usually live for longer than a single season, decrease annually. The results summarized in *Figure 3* were obtained by estimating the wireworm populations in soil samples taken in spring and autumn after permanent pasture was ploughed and reseeded with grass or lucerne. The numbers of wireworms increased annually in the pasture and were stable in the plots reseeded to grass, but in the plots planted to lucerne they diminished greatly in the first and second year and recovered slightly in the third year.

Although the numbers of short-lived micro-arthropods in soil become fewer when soil is first cultivated they usually recover by the next season unless the land is kept fallow. By contrast cultivation may have lasting effects on populations of arthropods that live for more than one year.

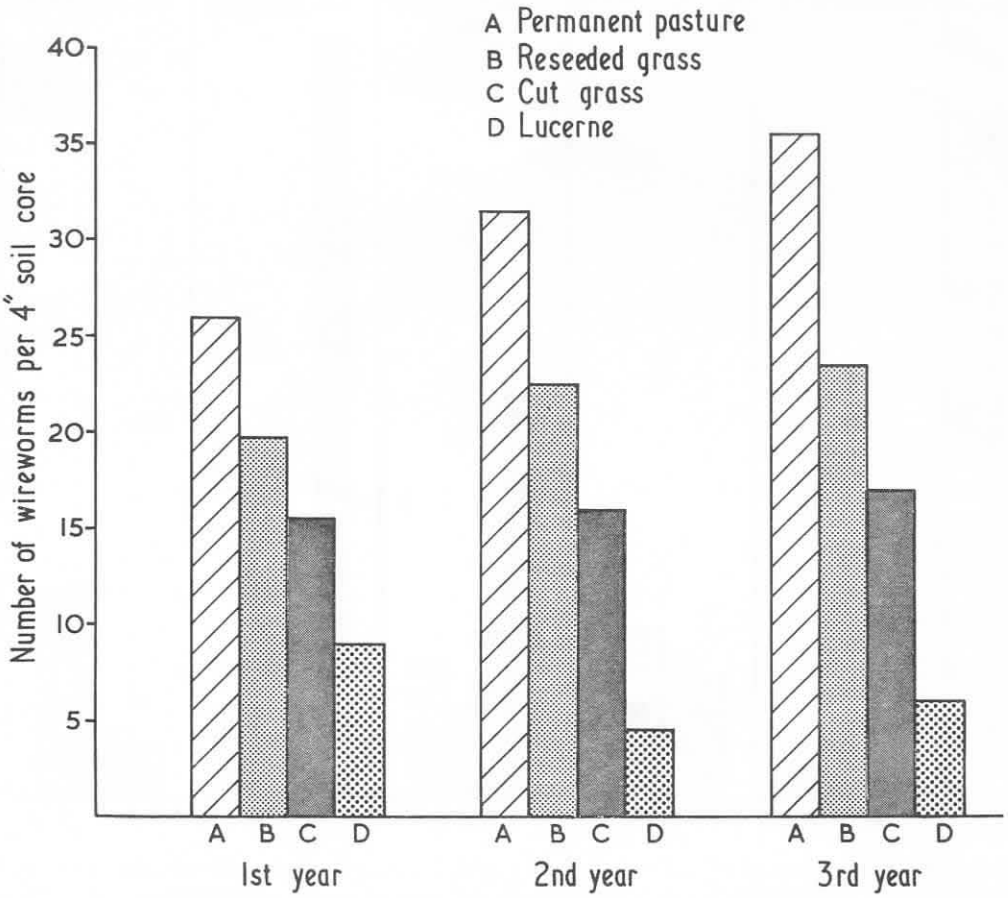

FIGURE 3. Effect of cultivation on populations of larval Elateridae (wireworms).

Some pests are more abundant in cultivated soil than in soil under woodland or pasture and *Figure 4* shows there are more Symphyla in some types of cultivated land. Many sites were surveyed and populations were largest in greenhouse soil, which is heated, irrigated and rich in nutrients.

Both organic manures such as dung and inorganic fertilizers can affect the numbers of microfauna, the former by providing organic matter for them to feed on and the latter indirectly through their effect on the growth of plants and micro-organisms. *Figure 5* compares the numbers of Collembola and Acarina in plots without fertilizer with those treated with dung and others with inorganic fertilizers. Most micro-arthropods occurred in plots treated with dung although there were more in the plots with inorganic fertilizer than in unfertilized plots. Sampling the long-term

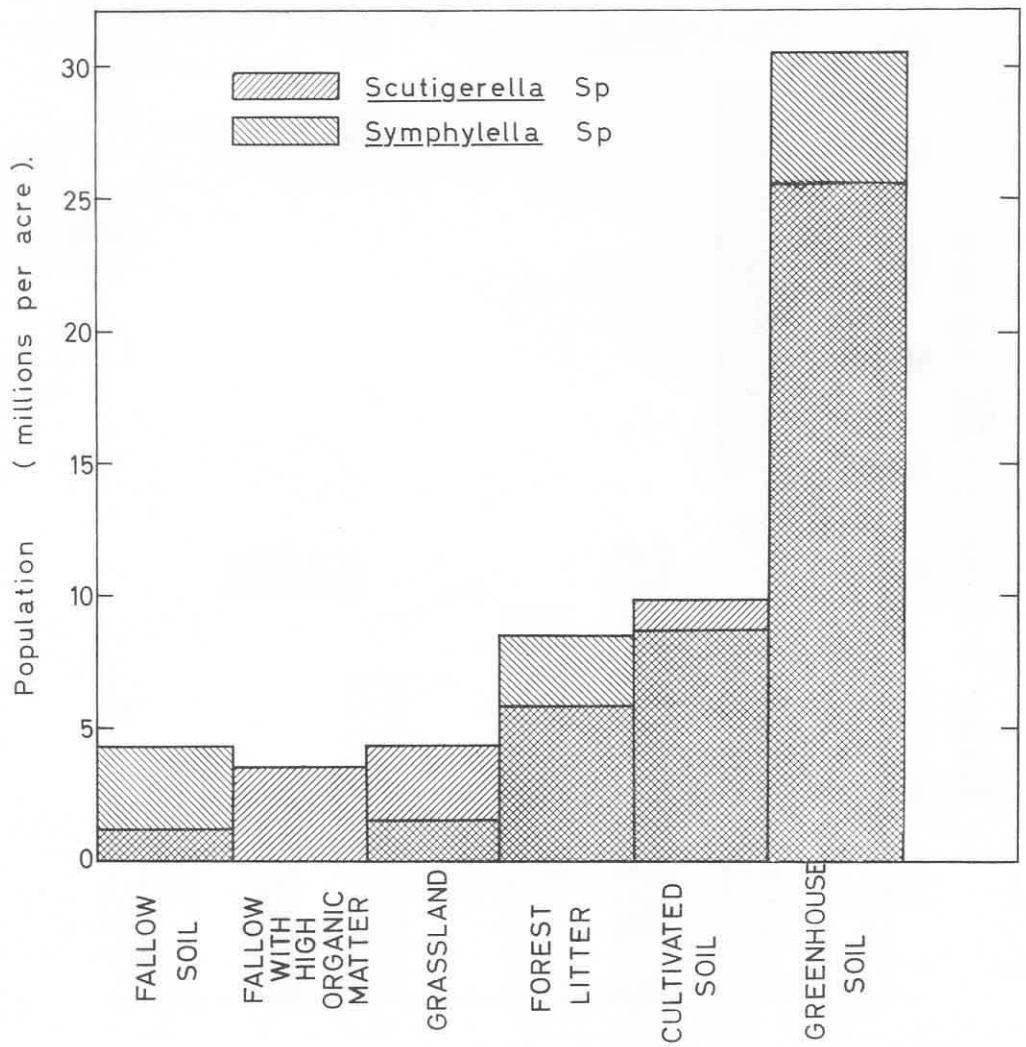

FIGURE 4. Populations of Symphyla in various habitats.

grassland fertilizer experiment at Rothamsted (Park Grass) showed that soil pH affected numbers of micro-arthropods, with most occurring in plots to which lime had been added.

There is little direct evidence on how drainage or irrigation affects arthropod populations. We have followed the changes in populations of arthropods in a sandy loam soil with regular irrigation and preliminary data suggest that irrigation increases numbers.

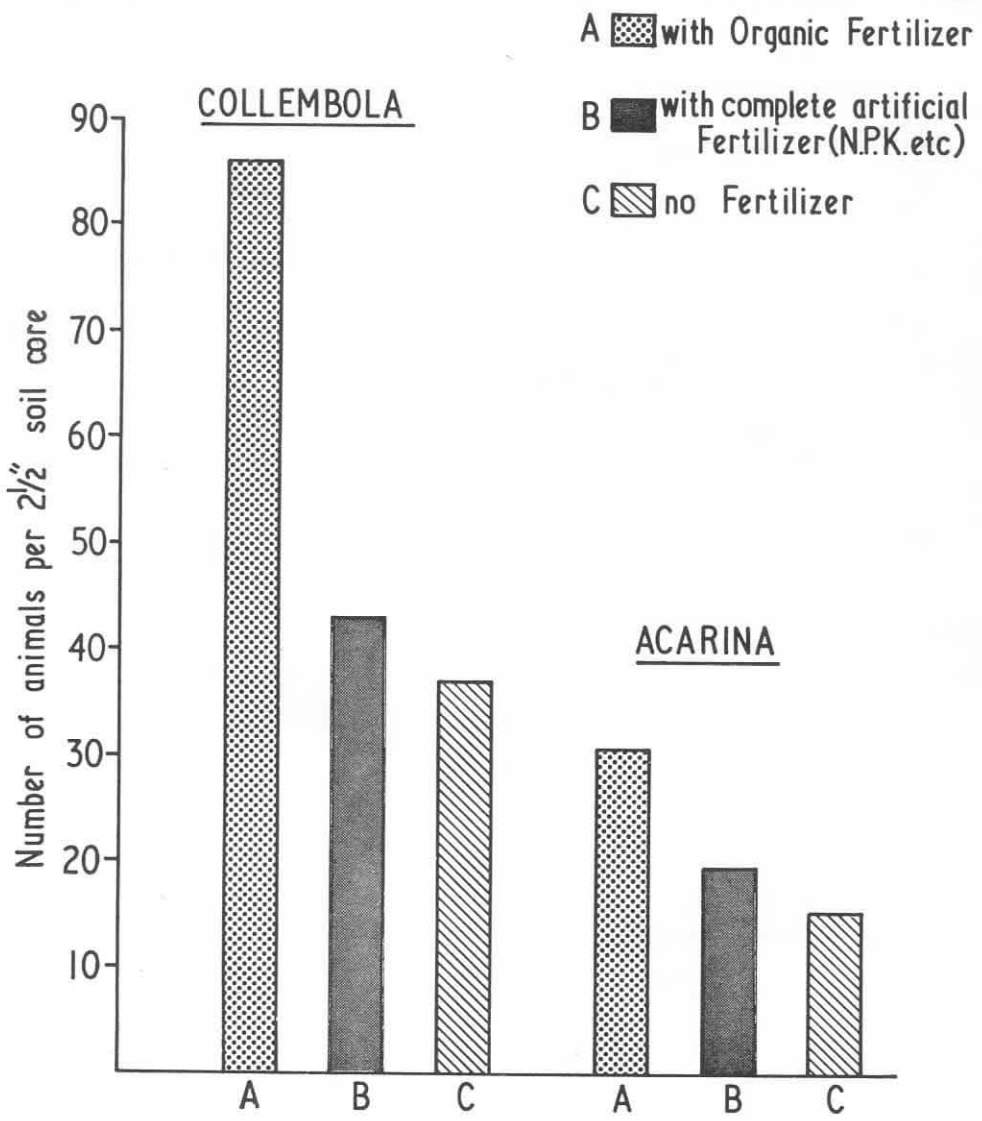

FIGURE 5. Effect of fertilizer on soil micro-arthropod populations.

EFFECTS OF PESTICIDES ON POPULATIONS OF MICRO-ARTHROPODS

We have investigated the effects of pesticides on soil invertebrate populations during the last eight years (EDWARDS and DENNIS, 1960; EDWARDS, 1963; 1964; 1965; 1965*a*; EDWARDS and JEFFS, 1965; EDWARDS, DENNIS and EMPSON, 1967; EDWARDS, THOMPSON and BEYNON, 1967).

The fumigants DD and Vapam have drastic effects on arthropod populations, usually killing more than 99 per cent of the original numbers, and it may take more than two years for the population to recover completely although the chemical itself disappears in about four weeks. The Diptera and Collembola are the first arthropods to recolonize treated soil and, with little competition, they multiply rapidly.

Herbicides may affect soil arthropods directly, or more important, indirectly, by destroying weeds and eliminating much of the decaying plant debris on which many soil arthropods feed. We have tested many herbicides for direct effects on numbers of soil arthropods, but only simazine and DNOC decreased their numbers and this only slightly and for a short time. For instance, after treatment with simazine, arthropod numbers recovered within four to six months, which is about the time that the chemical persists in the soil. Although DD disappears much sooner than simazine, its effects last much longer, i.e. the degree to which arthropod populations are affected is a product of the toxicity of the chemical and its persistence (*Figure 6*).

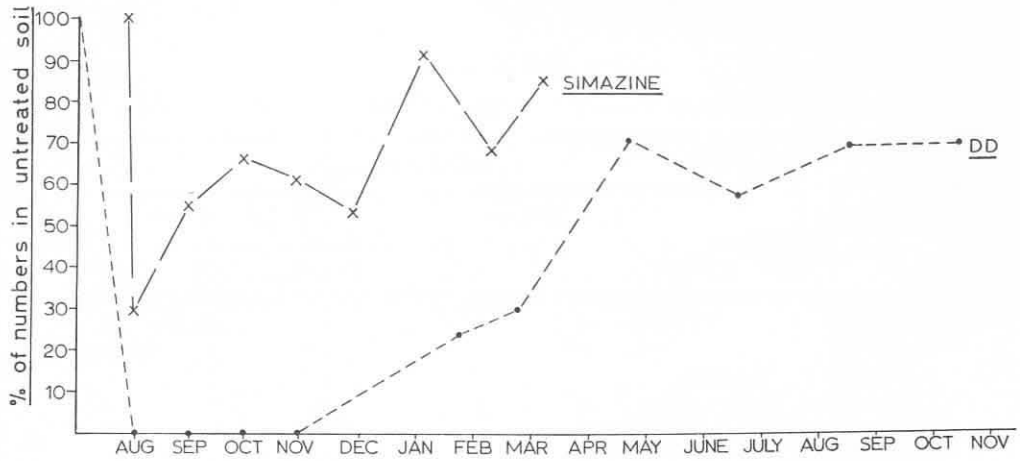

FIGURE 6. Recolonization of soil treated with DD and simazine by Collembola.

The chlorinated hydrocarbon insecticides, especially DDT and dieldrin, influence arthropod numbers for the longest time. Most micro-arthropods have two peaks of population, one in spring and a larger one in autumn, and these insecticides affect populations most during these times. Differences between treated and untreated soils are least in summer and winter when populations are smallest. The commonest insecticide residues in agricultural soils are those of aldrin and DDT, and they have very different effects. Aldrin is more toxic than DDT to most soil arthropods (except Mesostigmata which are not affected by aldrin). DDT greatly diminished

numbers of mesostigmatid mites but had little effect on Collembola, so DDT treatments to soil invariably increases numbers of many of the commoner species of Collembola by destroying their principal predators.

Chlorinated hydrocarbons often affect numbers of soil micro-arthropods much less than cultivation, so it seems unlikely that their effect on micro-arthropod numbers have any influence on soil fertility. With new techniques of minimal or zero cultivation, soil arthropods may have a much more important role in soil aeration and turnover than with the conventional methods of cultivation. The potential danger of persistent insecticides is that they continue to kill soil arthropods even after land has been returned to pasture or woodland and hence have possibly important long-term effects on soil fertility.

Chlorinated hydrocarbon insecticides are being less used in the United Kingdom and are being replaced by organophosphorus and carbamate insecticides. We have tested many, including diazinon, parathion, menazon, disulfoton, phorate, thionazin, fenitrothion, carbaryl and others for their effects on soil micro-arthropod populations. None of them affected arthropod numbers as much as do the chlorinated hydrocarbons. However, they consistently change the balance between the mesostigmatid mites and their prey, which may consist of Collembola, and oribatid or even trombidiform mites (EDWARDS *et al.*, 1967). As long as the insecticide is present, which is usually between one and six months, with a "half-life" ranging from two to four weeks, Mesostigmata are killed. For the first two months, populations

TABLE 1

Effects of insecticides on the number of species in soil arthropod communities

Group	Number of species					
	Arable field			Pasture field		
	Control	DDT	Aldrin	Control	DDT	Aldrin
Pauropoda	4	3	–	4	2	1
Symphyla	2	1	2	2	1	2
Chilopoda	3	2	2	3	2	1
Diplopoda	2	2	1	2	2	2
Prostigmata	7	6	6	22	17	16
Mesostigmata	7	6	6	26	14	17
Astigmata	2	2	1	7	3	4
Cryptostigmata	–	–	–	18	15	18
Onychiuridae	2	2	2	3	3	3
Poduridae	–	–	–	2	2	1
Isotomidae	5	5	5	8	8	4
Entomobryidae	3	3	3	3	3	3
Sminthuridae	2	2	2	8	8	6
Thysanoptera	5	3	1	13	8	6
Coleoptera	7	2	3	7	4	5
Diptera	14	8	6	19	16	9
Lepidoptera	1	1	–	1	1	1
Total	66	48	40	148	109	99

of other mites and Collembola may be somewhat diminished but then begin to increase, often to several times the number found in untreated soil. These increases may continue for as long as six months after most of the insecticide has disappeared, but they are seldom prolonged into the second season. Thus, although organophosphorus insecticides may greatly change the species and numbers of micro-arthropods in the ecosystem for a single season, they seldom do so for longer.

QUALITATIVE CHANGES IN SOIL MICRO-ARTHROPOD POPULATIONS DUE TO AGRICULTURAL PRACTICE

There are fewer species of arthropods in cultivated than in uncultivated soils, although there are few carefully documented studies supporting this conclusion. It is apparent that growing a single species of plant in a habitat tends to eliminate those arthropod species associated with other plants. Rotations of crops in which different species of plants are grown in successive years probably decrease the numbers of animals and species remaining after cultivation even more than monoculture. Arthropods that can fly and so can readily recolonize soil are probably less affected than those species less able to migrate easily to new habitats.

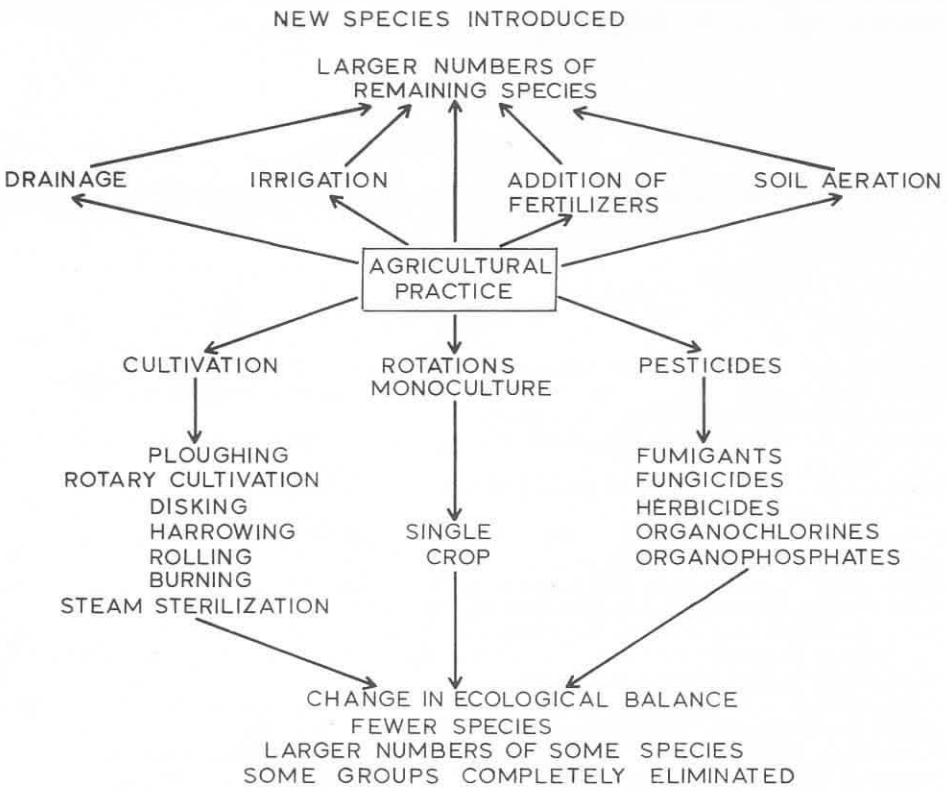

FIGURE 7. Ecological effects of agricultural practice on soil micro-arthropod populations.

Cultivation soon eliminates species susceptible to damage, desiccation and destruction of their microhabitats. Pesticides are also selective in their action and groups or species especially vulnerable to them may not be able to survive when the pesticide persists for several years or is applied annually. *Table 1* compares the numbers of species in cultivated soils with those in the same soils treated with 4 lb active ingredient of either aldrin or DDT. Aldrin diminished numbers of species more (60 per cent and 67 per cent of control species) than did DDT (73 per cent and 74 per cent of control species) but neither insecticide had a drastic effect on numbers of species.

It is difficult to generalize about which groups of arthropods are most affected by agricultural practice. Symphyla, Protura, Diplopoda, rhodacarid and some trombidiform Acarina, sminthurid Collembola and some Diptera and Coleoptera seem to be more abundant in agricultural habitats than elsewhere. Conversely, Isopoda, some Chilopoda, oribatid Acarina and some Diptera and Coleoptera are rare in cultivated or pasture soils. Many groups have some species that increase numerically in uncultivated soils but not in arable soils, and for other species the converse is true.

The ways in which agricultural practice may affect micro-arthropod populations are outlined in *Figure 7*. Such features as growing a single crop, cultivation and use of pesticides make populations smaller. Practices such as drainage, irrigation and fertilizer usage may encourage multiplication of the fewer remaining arthropod species. Although we have considerable information on populations of micro-arthropods in agricultural soils much information is still needed, especially on the interactions between the different species of micro-arthropods.

ACKNOWLEDGMENTS

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DISCUSSION*

Mr W. WILKINSON: I should like to comment on the observation that, in the comparison of ploughed land with unploughed paraquat-treated land, differences in micro-arthropod populations disappeared after six months. At Jealott's Hill we have a trial of this nature which has now been running for six years, and the micro-arthropod populations on the paraquat-treated direct-drilled plots are consistently at a considerably higher level. This is due presumably to improved microhabitats and lack of mechanical disturbance. Species proportion is also different.

*Time did not permit a full discussion of this paper. Ed.